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SPRAYING FOR THE CONTROL OF INSECTS AND MITES ATTACKING CITRUS TREES IN FLORIDA

UNDER FLORIDA CONDITIONS spraying is the most effective method for the control of citrus pests. In the past there have been many failures, and much money has been expended without adequate returns to the grower. These failures have been due to various causes, such as improper equipment, ineffective insecticides, and lack of a proper spraying schedule.

This bulletin gives information regarding the best equipment for Florida conditions, and directions for preparing effective insecticides. There is also given a spraying schedule that has proved satisfactory after several years of practical experience and such other information as will enable the grower to control citrus pests in a satisfactory manner.

Spraying improves the grades of the fruit and increases the yield of the trees out of all proportion to its cost, if the work is done properly.

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SPRAYING FOR THE CONTROL OF INSECTS AND MITES ATTACKING CITRUS TREES IN FLORIDA.

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CONTENTS.

CITRUS INSECTS AND MITES OF IMPORTANCE.

MORE than 95 per cent of the total damage caused to citrus trees by insects and mites in Florida may be attributed to six species. These are, in the order of their destructiveness, the citrus white fly (figs. 1, 2, 20),[1] the purple scale (fig. 4),[2] the rust mite (fig. 6),[3] the Florida red scale (figs. 4, 5),[4] the cloudy-winged white fly (fig. 3),[5] and the red spider or six-spotted mite.[6] There are several other pests of minor importance, such as the woolly white fly (fig. 7),[7] the purple mite,[8] the chaff scale,[9] and the citrus mealybug (fig. 8).[10] The citrus white fly, the most injurious of pests, now infests nearly all the groves of Florida, and the purple scale is found in greater or less numbers on every citrus tree.

LOSSES RESULTING FROM INSECT ATTACK.

The presence of pests on citrus fruit usually causes blemishes that place such fruit in a lower grade. It is generally considered that fruit which has been attacked by the rust mite is also one size, or

[1] *Dialeurodes citri* (Ashmead).
[2] *Lepidosaphes beckii* (Newman).
[3] *Phyllocoptes oleivorus* (Ashmead).
[4] *Chrysomphalus aonidum* (Linnaeus).
[5] *Dialeurodes citrifolii* (Morgan).
[6] *Tetranychus sexmaculatus* Riley.
[7] *Aleurothrixus howardi* (Quaintance).
[8] *Tetranychus citri* McGregor.
[9] *Parlatoria pergandii* Comstock.
[10] *Pseudococcus citri* (Risso).

12½ per cent, smaller than it would otherwise be. Fruit without blemishes caused by pests probably will reach the market with less decay.

The better grades of fruit are more marketable. High-grade fruit finds an early and ready market. Fruit badly attacked by insects and mites is usually sold late in the season, after sustaining large losses from dropping and incurring the liability of damage from frosts.

FIG. 1.—Adults of the citrus white fly crowding the under surface of new orange leaves. Adults appear slightly less than normal size. (Morrill and Back.)

The work of the pests devitalizes the trees. Much of the bearing wood on the inside of the tree is killed, thus reducing the yield. It requires much additional fertilizer to produce a crop of fruit when pests are present.

METHODS OF CONTROLLING CITRUS PESTS IN FLORIDA.

Florida growers have attempted to control citrus pests by three methods: (1) Fumigation, (2) spraying, and (3) encouragement of entomogenous fungi, that is, those which live upon insects.

FUMIGATION AND SPRAYING.

Of the two artificial methods of control, spraying and fumigation, spraying is superior under Florida conditions at present. Fumigation—excellent as it is under weather conditions such as exist in California—is not promising in Florida, where the dormant season for citrus trees is too short to permit the advantageous use on a large scale of fumigating outfits. There are also other objections to the general adoption of fumigation for the average grove in Florida. On some groves, however, fumigation[11] could be used successfully. With the recently originated

[11] Morrill, A. W. "Fumigation for the citrus white fly, as adapted to Florida conditions." U. S. Dept. Agr., Bur. Ent. Bul. 76.

gas-tight tents and liquid hydrocyanic acid, fumigation in the future may be highly satisfactory under Florida conditions.

FUNGI.

FIG. 2.—Pupæ and pupa cases of the citrus white fly. The pupa cases do not collapse after the adult emerges, like those of the cloudy-winged white fly, but remain rigid. (Morrill and Back.)

There are a number of fungi that kill insects and mites in Florida. These do an immense amount of good and should be present in every grove in the State. The most valuable of those killing citrus insects and mites are the red-headed[12] and gray-headed[13] fungi that kill the purple scale, and the red (fig. 9),[14] yellow,[15] brown (fig. 10),[16] and white-fringe[17] fungi that kill white flies, a mealybug fungus, and a rust-mite fungus. Under the most favorable climatic conditions these fungi keep the insects and mites well in check. These favorable conditions many times do not obtain, and scale insects, white flies, and rust mites become abundant and cause much damage, often before a grower realizes the situation. These fungi are active about five months during the rainy season in summer, leaving many of the injurious insects to multiply unchecked during the remainder of the year. The fungi kill the insects only after the tree has given up its vitality to furnish nourishment for the insects' development. In many instances when fungi are depended upon as the only method to free trees from insect attack, the trees are left in a weakened condition, often with

FIG. 3.—Pupa cases of the cloudy-winged white fly. They are very filmy, collapse after the adult emerges, and fall easily from the leaf. (Morrill and Back.)

[12] *Sphærostilbe coccophila* Tul.
[13] *Ophionectria coccicola* E. & E.
[14] *Aschersonia aleyrodis* Webber.
[15] *Aschersonia flavo-citrina* P. Henn.
[16] *Aegerita webberi* Fawcett.
[17] *Microcera* sp.

much dead bearing wood and sparse foliage, before the fungi succeed in temporarily reducing the insects to a point where little damage follows.

SPRAYING COMING INTO GREATER FAVOR.

More than 12 years ago, before the Bureau of Entomology had given out recommendations for the control of white flies and scale

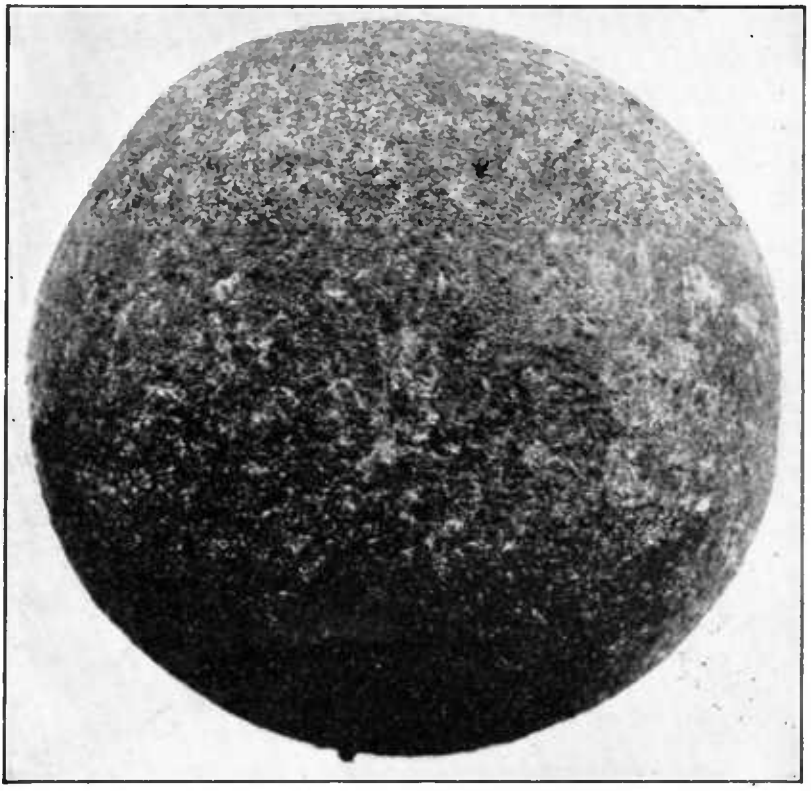


FIG. 4.—A grapefruit heavily infested with both the Florida red and the purple scales in all stages of development. Note that the scales form a scurf over the rind.

insects by spraying, very little spraying had been done to control these pests. Enthusiastic supporters of control by natural agencies contended that it is more profitable to grow lower grades of fruit without treatment than the better grades with treatment. Yet a system of spraying for improving grove conditions has been gradually adopted by men who, only a few years ago, depended entirely upon fungi as the best all-around means of control. This change from total dependence upon fungi to spraying with insecticides has come partly through the realization that entomogenous fungi, excellent as they are, are not a complete means of insect control, but

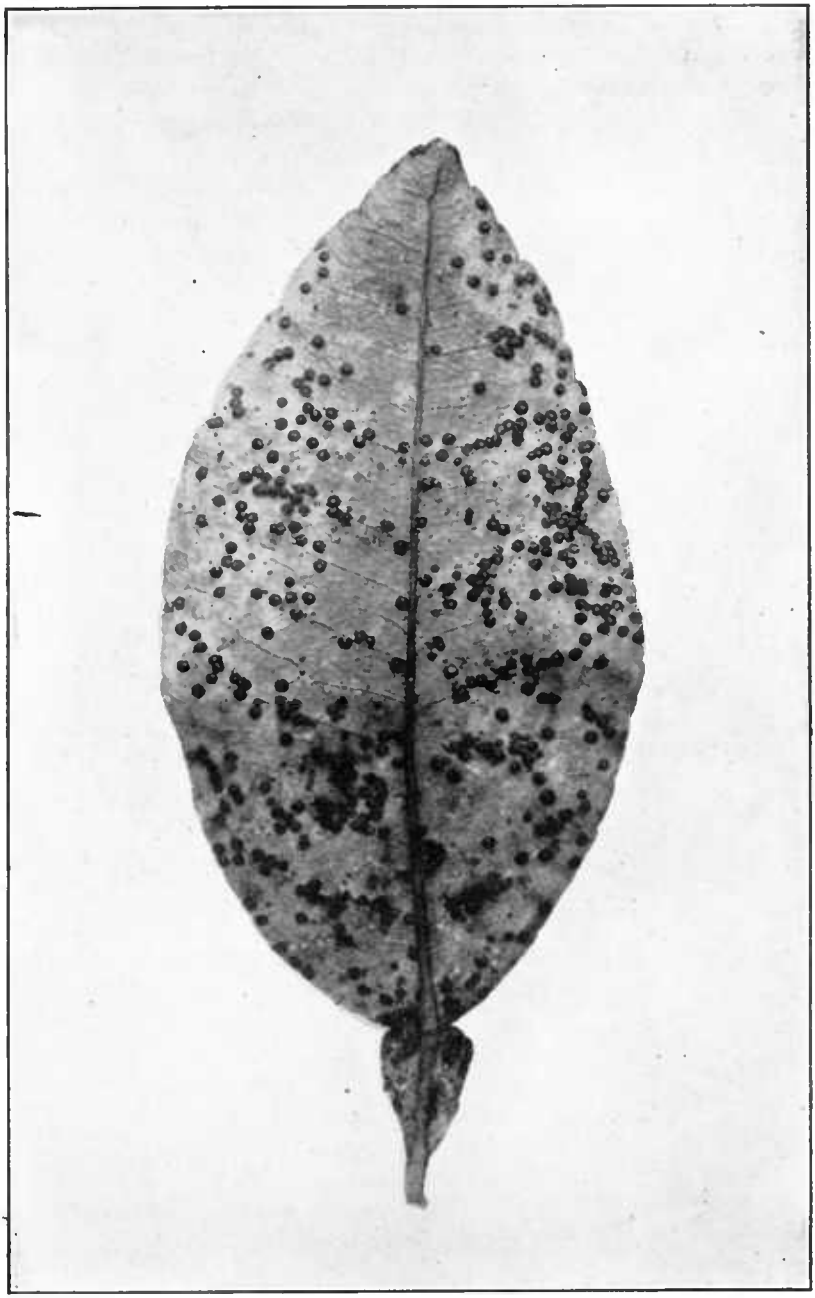


FIG. 5.—The Florida red scale, showing the adult females and young scales.

should be supplemented by spraying with insecticides. The growing use of spray mixtures and the spraying schedule advocated in this bulletin has also been an influential factor in bringing about this change. Spraying as a method of control has been followed successfully in Florida by many who are acknowledged to be successful growers.

REASONS FOR BAD RESULTS IN THE PAST.

Spraying, however, taken throughout the citrus area, has not yielded satisfactory results, and growers have become discouraged for two main reasons: (1) Lack of reasonable thoroughness on the part of laborers, and (2) lack of a proper appreciation of the requirements for spraying on the part of the grove owner.

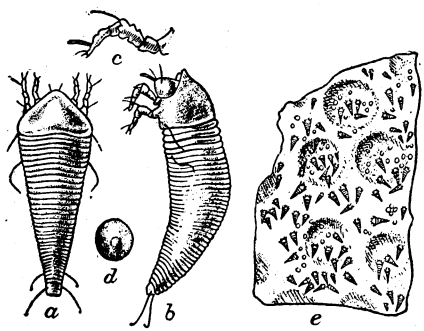


FIG. 6.—The rust or silver mite: *a* and *b*, Dorsal and lateral views of adult mite; *c*, leg of same; *d*, egg; *e*, lemon rind showing pits normal to surface and mites and eggs. All greatly enlarged. (*a* to *d*, Copied from Hubbard; *e*, Marlatt.)

Because success did not follow a single haphazard application of an ineffective insecticide, spraying has been pronounced a failure by many. The writer has examined leaves from sprayed groves and found not more than 10 per cent of the insects killed. He has known personally of instances in which grove owners have purchased reliable and expensive power sprayers, only to turn over the mixing of the insecticide and the spraying of the trees to uninstructed labor. Many fine groves have been sprayed by men who did not hit 40 per cent of the insects with the spray. One crew operating a power outfit did not hit the lower surface of more than one leaf in a thousand. Spraying can not succeed under such conditions.

EQUIPMENT FOR SPRAYING.

Much dissatisfaction in spraying for the control of pests on citrus trees arises from the use of inefficient equipment. The equipment for spraying should be adapted to the particular needs of the grower and also to the size of the trees and the nature of the grove to be sprayed.

PUMPS.

Barrel pump.—A barrel pump (fig. 11), which will supply one lead of hose, will serve every purpose if the trees are low and only a small amount of spraying is required, and will save investment in a

FIG. 7.—Orange leaf infested with the woolly white fly.

large machine until such time as the work necessitates one. For three years or longer after planting, this pump will answer the purpose very satisfactorily. In fact, one of the most successful grove owners, who sprays, has used a barrel pump for three years in his grove of 800 trees about 10 feet in height. A barrel pump, indeed, is a necessity in any grove where insects are controlled by spraying. Many times it is necessary to spray one tree only, and this can be done easily with a barrel pump, thus eliminating the necessity of using a large machine. A barrel pump is also suitable for spraying in groves where palmetto and other trees have not been removed, and in groves so thickly planted that it is difficult to use a power sprayer. A barrel pump can be used also for making emulsions and for whitewashing.

FIG. 8.—Heavy infestation of mealybugs on grapefruit.

For extensive operations, however, experience indicates that either a large lever pump or a gasoline power outfit should be used.

Lever pump.—The large double-acting hand pump (fig. 12) can be used for spraying even the largest trees and may be recommended for groves as large as 10 acres. This type of pump, like the barrel pump, seldom needs repairs and will supply two nozzles very satisfactorily. These pumps can be purchased in connection with a tank or separately. If purchased separately, a barrel is used to hold the spray material. The chief difficulty with both the barrel pump and the lever pump is the fact that it costs at least the wages of one man to furnish the power. This usually amounts to about 6 to 10 times as much as the cost for gasoline to run a power outfit. Another disadvantage in using any type of hand-power pump is the irregularity of the pressure and the lack of stimulus to the men that is furnished by a power-driven machine.

Gasoline power outfit.—For any extended work in spraying, a power outfit (figs. 13, 14) should be used. Owing to the nature of the soil in Florida, spraying machines should be made as light in

weight as possible. It is very doubtful if any machine that weighs more than 1,800 pounds is practical under the average grove conditions in Florida. To be of the greatest value a machine should weigh not more than 1,400 to 1,600 pounds. It is also desirable in many instances to have a cross reach for the truck which will permit it to be turned in a very small circle. The tires should be not less than 6 inches in width and the diameter of the wheels should be as great as is practicable. In many instances, however, where the branches of the trees are near the ground, it is desirable to have the machine as low as possible to prevent pulling off fruit and leaves. Some machines are built unnecessarily high and when used in such a grove cause much damage.

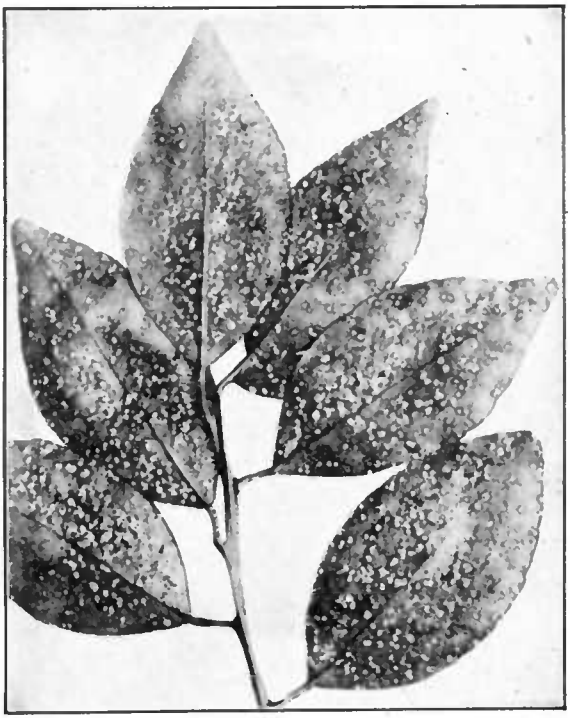


FIG. 9.—Red fungus attacking citrus white fly. (Morrill and Back.)

Since the wheels with which the spraying machines are fitted are extremely heavy, often comprising half of the weight of the empty machine, it is extremely desirable that lighter wheels be constructed for this special purpose. A machine for Florida conditions should be fitted with a tank located in front of the engine and pump (*not* as in fig. 15.) This gives the operator an opportunity to attend the engine from the rear of the outfit without interfering with the team, and also eliminates the danger which usually follows when an engine is placed immediately in the rear of a pair of mules. The tank should contain an opening large enough to permit a man to go inside to clean it out. The opening should be fitted with a removable fine-mesh wire strainer. The tank and the cab over the engine and pump should be flush with each other, in order to prevent the catching of branches, carrying off of fruit, and other injury to the trees.

The engine should be not less than 1½ horsepower. It is the consensus of opinion that a light engine of 2½ horsepower is preferable to one of less power. The engine by all means should be fitted with a good governor. The pump should have sufficient capacity to supply as many nozzles as it is intended to use. Probably a pump having a capacity of not less than 5 gallons per minute should be used. Most of the better-grade pumps have a capacity of from 7 to 11 gallons per minute, and these will supply four or more nozzles. The pump should be fitted with a regulator which is accurate, and will take care of the capacity of the pump whether the nozzles are turned on or off. The pressure should not vary if the nozzles are cut off. Both the engine and the pump should be protected from sand by means of canvas curtains on the sides and rear. The wheels raise considerable sand to the height of the engine and pump and the wind may then blow it into the machinery. The writer has known of instances in which machinery unprotected from the sand has been ruined in a single week.

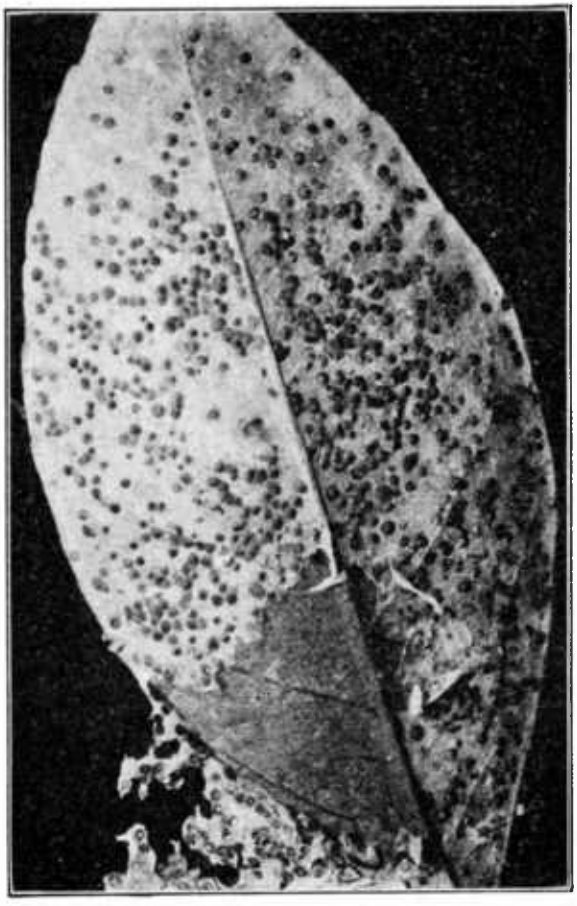


FIG. 10.—The brown fungus attacking the citrus white fly. The mycelium of the fungus has been turned back from the lower left portion of the leaf. (Morrill and Back.)

Roller sprayer.—The roller sprayer is a new type of spraying machine which has met with great favor during the last three years. Owing to the sandy soil in which most citrus groves are planted, it is very difficult for the average team to handle the wheel-type spraying machine containing 200 gallons of material. The roller

sprayer eliminates this difficulty perfectly and one horse can handle 200 gallons of spraying material very easily. An engine and a pump of the same kind as those that are used on the wheel type of machine may be placed on the roller sprayer. This machine is illustrated in figure 16.

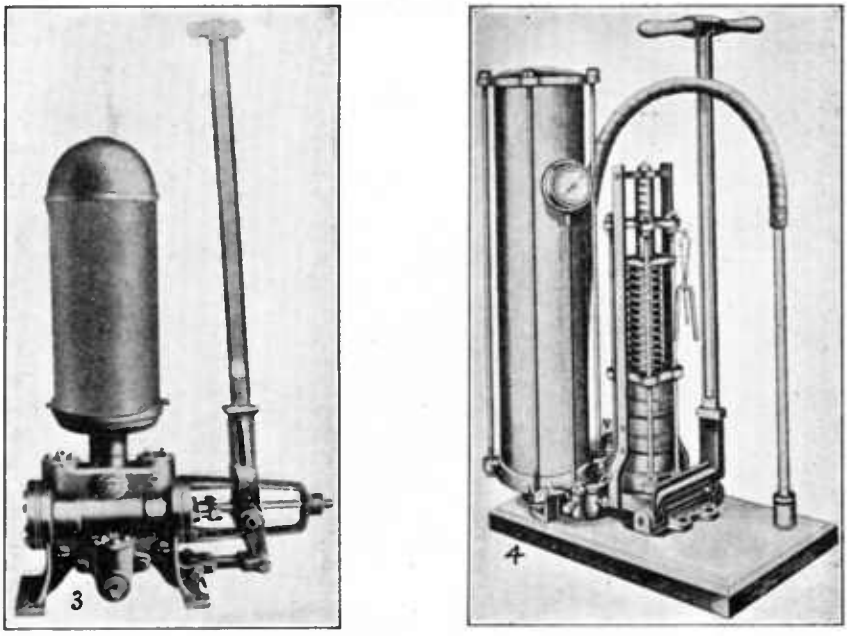
FIG. 11.—A barrel pump is satisfactory for small operations. The spray is directed upward to hit the white fly infesting the lower surfaces of the leaves.

HOSE.

The same kind of hose should be used for the barrel pump, the larger lever pump, and the power outfit. This hose should be not less than 7-ply if it is "wrapped." There is also a hose which is known as "double continuous net weave," which has given satisfactory results. This type is much lighter, and is therefore much easier to handle in a grove than the heavier type. So far, however, there are no indications as to whether the wrapped or the

woven hose is superior. It is useless to attempt to spray with ordinary garden hose, even when using a barrel pump. The writer has broken garden hose in one hour. Hose should be smooth on the outside instead of corrugated, since smooth hose can be repaired by wrapping with adhesive tape. The best size to use is hose of one-half inch diameter.

For convenience in operation leads of hose should be 50 feet long. Hose of this length permits the operator to reach the farthest side of the largest trees in groves where they are planted at the average



1. 2.

FIG. 12.—These hand-power tank outfits are satisfactory for many groves in Florida. They are durable and do not easily get out of repair. They will supply two leads of hose, and may also be used in making emulsions. (Quaintance.)

distance. Since the hose wears out first at the point of attachment to the machine or rod, this length permits the hose to be cut off and reattached without making it too short. With a long hose both the mules and the machine may be kept out of range of the spray.

RODS.

In spraying, an extension rod ranging from 8 to 12 feet in length should be supplied with each line of hose. The length will depend upon the height of the trees. This rod may be a regular bamboo rod or a small gas pipe. The former is more suitable for this work because it is lighter and more easily handled after becoming wet, and

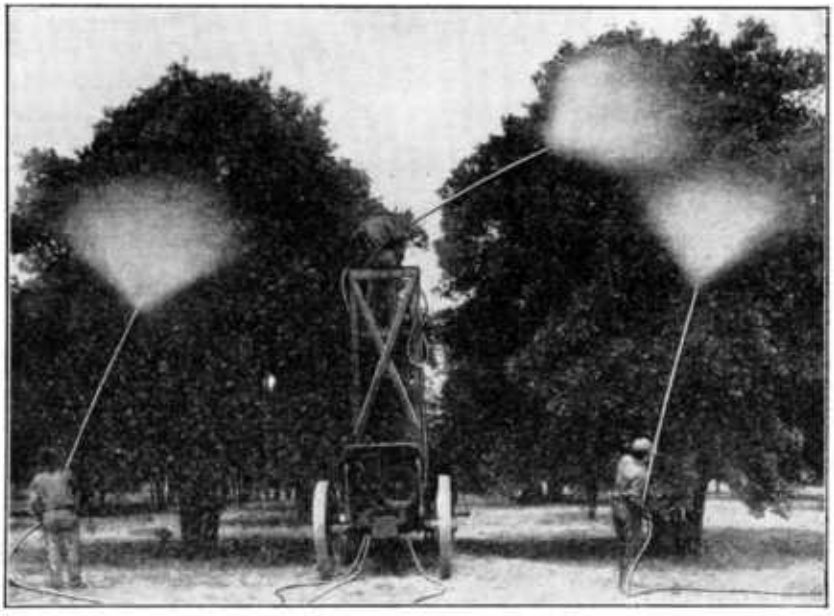


FIG. 13.—A power spraying outfit of the approved type with the engine in the rear, where it can be attended without loss of time. Note the tower which enables the sprayer to reach the topmost branches of the trees.

FIG. 14.—Water supply wagon to the right of the spraying machine. Such a wagon, used to haul water to the machine in the grove, nearly doubles the number of the trees that can be sprayed without much additional cost. Note that the cover over the engine is flush with the spray tank.

is not easily bent, hence the operator always knows just how to turn the rod to direct the spray upward. The bamboo rods, however, will not stand such rough usage as those made of gas pipe, and for this reason many growers have stopped using them. An old piece of rubber hose may be slipped over the end which is attached to the hose, so that the operator may handle the rod with greater facility. Rods of gas piping should be kept straight and they should never exceed 10 feet in length. Owing to the more thorough work that can be done with the light bamboo rods, and the greater ease with

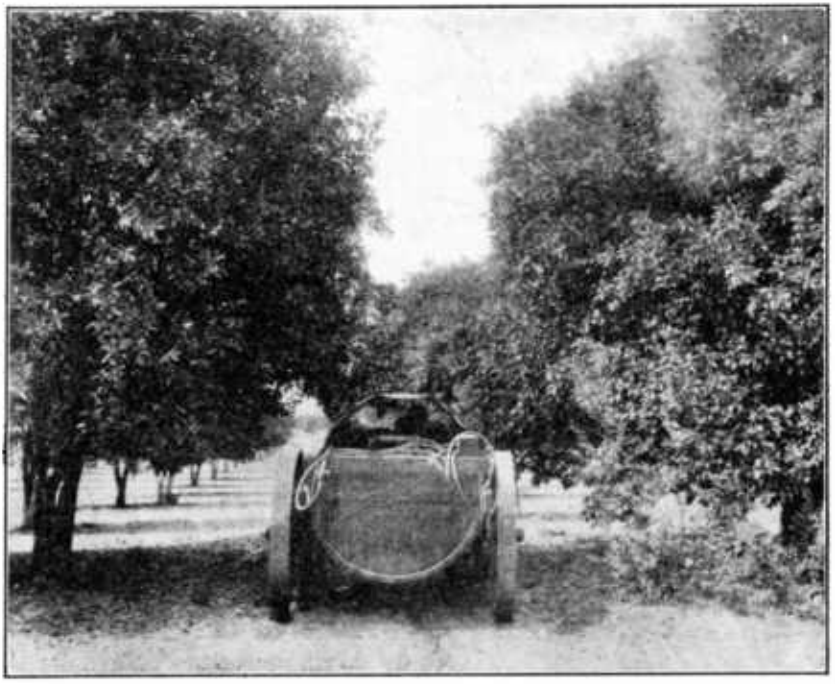


FIG. 15.—A power spraying machine of the undershung type, with the engine and pump forward, the tank in the rear.

which they may be handled, they should be used whenever practicable. With care they often last for years.

CUT-OFFS.

There should be a cut-off between each line of hose and the machine, so that if only one line of hose is required, or if an accident temporarily incapacitates one lead, the other lead or leads can be used. There should be an additional cut-off between each extension rod and the hose, so that the operator can prevent any undue waste of spray material, either in going from row to row or from tree to tree. A cut-off placed in this position will enable the operator to clean out any

impediment in the nozzle without going back to the machine to cut off the liquid. A cut-off should always be kept in good repair, for if it does not cut off the spray *completely*, it is useless.

NOZZLES.

In spraying citrus trees the object is to obtain as wide a field as practicable so that the greatest amount of leaf surface can be sprayed in the shortest time. Penetration is not so important in spraying for the pests on citrus. An angle nozzle, from which the spray emerges in the form of a cone, at an angle of from 45° to 60°, is the best to

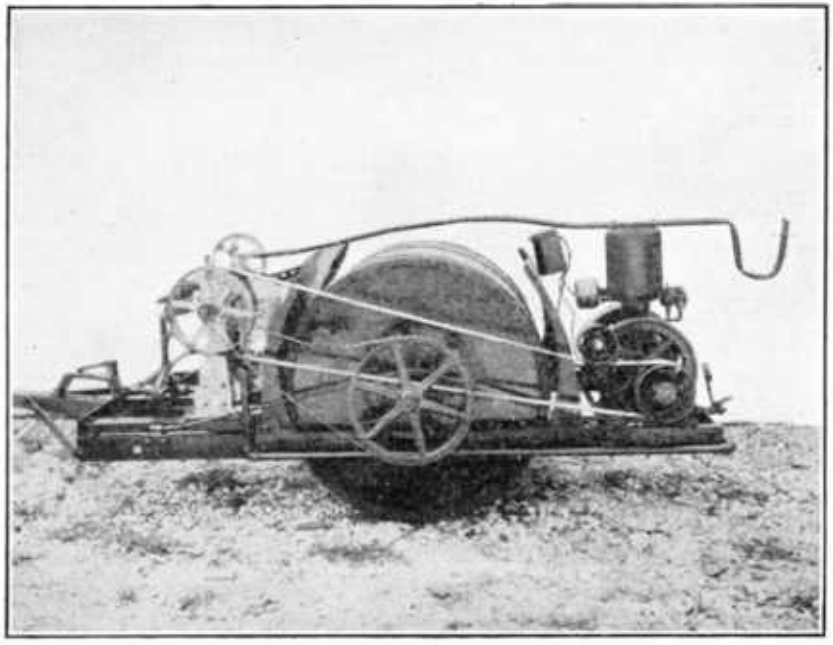


FIG. 16.—Roller sprayer, a new type of spraying machine adapted to Florida conditions.

obtain this result. It is also much better if two of these nozzles are placed on a Y so that the cones of spray intersect at from 8 inches to 12 inches from the nozzle. When so arranged the hollows of the cones are broken and it is much easier to attain a perfect wetting of all the foliage. The object in spraying a citrus tree should be the complete wetting of both the upper and lower surfaces of the leaves in the shortest possible time. The writer has found after many years' experience that much time is wasted in using nozzles of small capacity. It requires at least twice as long to spray a tree using a nozzle with too small a hole in the disk as it does using one of proper capacity. It is advisable to use a disk with an opening not less than one-twentieth of an inch in diameter and not greater perhaps than one-sixteenth of an inch.

SPRAY GUNS.

The so-called spray guns are not adapted for spraying for white flies and scale insects. It is impossible to do thorough work with them. The spray can not be directed upward so as to hit the under surfaces of the leaves, and neither is the field of spray wide enough to wet the branches 6 or more feet distant. These may be adapted for spraying for rust mites, where speed may be more important than thoroughness.

SPRAYING ACCESSORIES.

Every outfit, whether it be a barrel pump, a large lever pump, or a power outfit, should be fitted with a wrench, pliers, hammer, and such other tools as are necessary. It will also save much trouble and annoyance if the materials which are placed in the tank are first strained through *double thicknesses of cheesecloth.* This will cost only a few cents and, according to the experience of the writer, may save several dollars a day in time. In case a small leak appears in the hose it can be dried carefully with a cloth and repaired with adhesive or "tire" tape; this has been known to double the durability of a hose. Copper wire or other wire should be available in case hose connections should separate. Patent hose clamps are now to be had. Each outfit should be provided with proper measures and buckets to enable the operator accurately to calculate the amount of the insecticide used, besides buckets for filling the tank.

INSECTICIDES.

The pests of citrus trees considered in this bulletin may be divided into two groups with relation to the insecticides involved: (1) Those controlled by the soap-and-oil sprays, such as the white flies and scale insects; and (2) those controlled by the sulphur sprays, such as the rust mites and red spiders.

INSECTICIDES FOR WHITE FLIES AND SCALE INSECTS.

Experiments covering a 10-year period have shown that the best insecticides for controlling white flies and scale insects are those having a base of cheap lubricating oil or what may be termed "paraffin oil." These oils are made into emulsions according to the following formulas:

Fish-oil soap at the rate of from 5 to 8 pounds to 50 gallons of water in May, or from 12 to 16 pounds to 50 gallons of water during the winter season, is an effective spray that has been used for many years without injury to the foliage or fruit.

While both the fish-oil soap and the oil emulsions are effective in killing the white flies and scale insects, experience indicates that

the latter are far superior to the former under Florida conditions. This superiority is due to the physical properties of the oils. The high boiling point and great viscosity possessed by these oils make them operative over a longer period of time after application, and, too, they are only slowly affected by average temperatures and showers. Foliage sprayed with oil emulsions remains slightly oily in appearance and to the touch for several weeks. Fish-oil soap leaves no such evidence that the trees have been sprayed. The oil spray is much less affected by showers than is the fish-oil-soap spray. Summer showers falling after the oil spray has once had an opportunity to dry on the foliage have little effect in lessening the efficiency of the spray. Such showers, however, have a very evident effect upon the number of insects killed by the soap spray. The effectiveness of the weaker strengths of fish-oil soap is much more reduced by showers than is the effectiveness of the weaker strengths of oil sprays.

In experimental work on a large scale for the control of the citrus white fly the oil-emulsion sprays have given better results than have the soap sprays. This greater efficiency seems to be due, not to a higher percentage of larvæ and pupæ killed when the spray is applied, but to the effect that oil sprays exert upon unhatched eggs or upon the young larvæ hatching from them within 10 to 14 days after spraying. The oil forms a film over the eggs which prevents a large percentage from hatching, and the young larvæ from those which do hatch are killed either in the act of emerging from the shell or in crawling over the oil-coated leaf. No matter how efficacious an insecticide may be in killing larvæ and pupæ on the leaves at the time the spray is applied, if it does not either kill these unhatched eggs or remain operative long enough to kill the larvæ that subsequently hatch, much of the benefit of spraying is counterbalanced by reinfestation.

There are two ways of making the oil emulsions: (1) Without heat; (2) with heat. The first is called the "cold-stirred emulsion"; the second, the "boiled emulsion." Both kinds of emulsions are efficient, reliable, and easily made.

COLD-STIRRED EMULSION.

Formula.

Fish-oil soap:		
By weight	pounds	8
or		
By measure	gallon	1
Paraffin oil, 24° or 28° Baumé	gallons	2
Water	gallon	1

Directions for preparation.—In preparing the stock mixture, the soap should be put into a receptacle of about 5 gallons' capacity and the oil added while the mixture is being vigorously stirred. It is important that the oil be added in small quantities at first, and that the stirring be sufficient to keep the oil and soap in the form of an emulsion after each addition of oil. Thus, at first about a pint of oil should be added to the soap and the mixture stirred until no free oil appears. As the amount of oil is increased it should always be stirred or mixed thoroughly before the next addition is made. After the required amount of oil has been added and after free oil has ceased to appear on top of the soap, the water is slowly poured in, about 1 quart at a time. As previously stated, the only apparatus required to make this formula in a small way is an ordinary galvanized iron pail and a paddle.

The foregoing formula may be modified under certain conditions, as the quantity of soap will depend largely upon the time consumed in adding the oil and the amount of stirring; the amount of soap being lessened if the stirring be uniform and ample time be taken in the careful preparation.

To make this formula on a large scale, a 300-gallon cylindrical tank may be fitted with paddles, which are attached to a shaft in a vertical position, occupying the center of the tank. The shaft is fitted with a beveled gear on the upper end. A horizontal shaft is then connected with the vertical shaft by means of another beveled gear, while the other end has a pulley to connect with the engine. A series of brakes should be fitted to the sides of the tank to prevent the entire mass from turning around with the paddles. An entire barrel of fish-oil soap may be placed in this tank and the stirring begun at once. Two barrels of oil may then be run into the soap through an inch or 1½-inch hole in the end of the barrel, or the oil may be run out of the bunghole. After the oil has been added, either one-half or two-thirds of one barrel of water can be added to complete the preparation of the stock solution. In the final spray this should be so diluted as to contain about 1 per cent of oil by adding 1 gallon of the stock solution to 50 gallons of water.

It is also highly practicable to fit up a 50-gallon barrel in the same way as for the 300-gallon tank. By attaching a crank to the horizontal shaft the mixer can be run by hand instead of by an engine. Such a mixer, designed and used by Mr. J. A. Stevens, De Land, Fla., has been found practicable. The writer has used an ice-cream freezer for making an emulsion, by removing the can and adding a false bottom of 1-inch board to hold up the stirring gears. In fact, many different types of mixers can be constructed, depending on the material available and the scope of the work involved.

BOILED EMULSION.

Formula.

Paraffin oil	gallons	2
Water	gallon	1
Fish-oil soap	pounds	2
or		
Hard soap	pound	1

Directions.—Put oil, water, and soap into a kettle or other vessel that will stand fire, and heat to the boiling point. While still very hot, pump the material (see fig. 17) into another vessel and then back again. Emulsion can not be made by this formula without a pump; stirring is not sufficient.

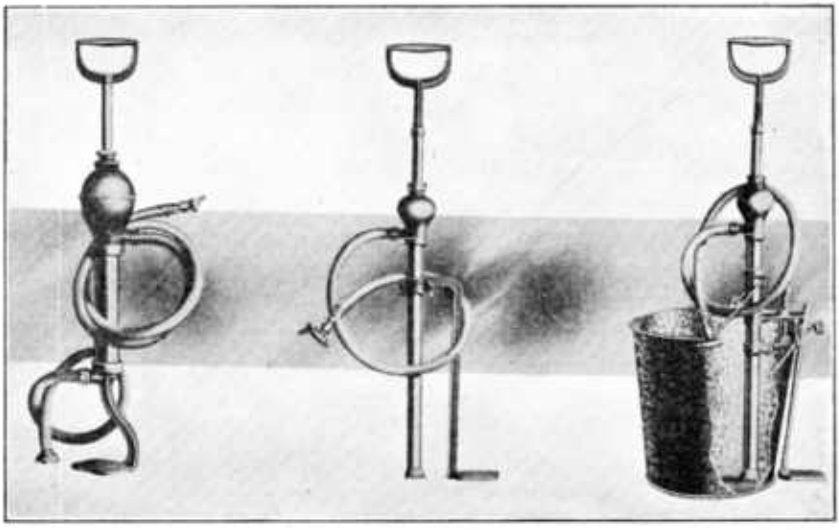


FIG. 17.—A pump used for emulsifying the oil. This is used in making the emulsions on a small scale. (Quaintance.)

Dilute to make 200 gallons of spray material.

For making the above formula the writer has used 9 and 15-gallon kettles, wash boilers, and 100-gallon oil tanks with uniform success.

If it is desirable to make this formula on a somewhat larger scale, the materials can be heated in a large kettle or other vessel and then dipped into a barrel pump outfit and the mixture emulsified by pumping it back upon itself. For safety it is best to have all the material pass through the pump twice, but it must not be pumped after it has become cool. Excessive pumping will break up a good emulsion. It can also be heated in a large galvanized oil tank having a capacity of 4 barrels and emulsified by means of the spraying machine. In this case the suction hose should be put into the tank of hot material and the discharge hose into the spray tank. For the second pumping, put

the suction hose into the spray tank and the discharge hose into the storage barrels. When the spraying machine is used for this purpose, an old suction hose should be used, as well as a discarded piece of hose for the discharge end. This should be not more than 10 feet in length. The material should be run through an ordinary nozzle with the disk left off. The overflow will not emulsify this material.

Both the "cold-stirred" and the "boiled" formulas have been extensively used in large citrus groves as well as by citrus growers' associations. One association has a plant fitted with two 300-gallon tanks and the material is heated by steam. To emulsify the mixture, they use a large pressure pump with a 2-inch intake and a discharge of ¾ inch. The material is pumped from one tank into another and then pumped over or back on itself for about 10 minutes. It is then barreled. This plant can make 3 barrels of insecticide in 20 minutes.

MODIFICATIONS OF FORMULAS FOR USE WITH DEEP-WELL WATER.

If it is necessary to use deep-well water for spraying, the same formula may be made up with a stabilizer such as ground glue, casein, milk powders, cornstarch, laundry starch, wheat flour, or corn meal. Any of these substances added to the foregoing formula will render the emulsion so stable that it will mix with practically all deep-well waters and also with lime-sulphur solution.

If it is intended to use the "*cold-stirred*" *formula*, the stabilizers can be added after the emulsion has been made or just before it is to be placed in the spray tank. Simply dissolve a pound of glue, either in hot water or by soaking overnight in a small quantity of water, and add this solution to 3 gallons of emulsion. Casein and milk powders can be used in the same way. If wheat flour, corn meal, cornstarch, or laundry starch are used, it will be necessary to make a paste, which can be added to the emulsion either when it is finished or just before it is to be used. These should be used at the rate of 1 pound to 3 gallons of emulsion.

If it is intended to use the "*boiled*" *formula*, the ground glue, cornstarch, laundry starch, or wheat flour can be placed in a kettle, together with the other materials of the formula, and no change need be made in the regular procedure. It is best, however, first to dissolve the materials in some water. It is also advisable to add the casein and milk powders after the receptacle has been taken from the fire or after the cooking process is over, but before the pumping or emulsification has been done. Of course, these stabilizers may be added to the emulsion just before it is to be used. All of these stabilizers are subject to fermentation, and they should not be used in insecticides if it is intended to keep them for any length of time. In extremely hot weather they will keep three days or longer. In

cool weather, of course, they will keep much longer. As yet we have not found a suitable and reliable preservative which will prevent these stabilized emulsions from breaking down.

Owing to the high temperature of the mixture, pumps used for emulsifying should have metal valves. If made of other material their period of usefulness is very short. It should always be remembered that a pressure pump must be used for emulsifying. The writer has never succeeded in making an emulsion with a rotary pump.

Difficulties that may arise in making the "boiled" formula are: (1) A lack of sufficient heat, (2) improper pumping, or (3) an improper emulsifier. In many tests the water and soap only were heated, and failure to produce a perfect emulsion resulted in every instance. On the other hand, when all the materials were heated together a perfect emulsion was secured. The materials should be heated until a slight foam or a few bubbles appear, but it is not necessary to boil for any length of time.

Some growers have failed because they attempted to stir the materials together with a stick, and others because they used a rotary pump. Neither of these is satisfactory.

The emulsifying agent is very important. There is no doubt that potash-fishoil soap is the most satisfactory of all soaps for the making of any of these emulsions. When this material is used the oil very seldom separates and the resulting emulsions never become too thick to be poured or handled conveniently. On the other hand, when hard soaps are used which are made from caustic soda and fats containing large proportions of stearin and small quantities of rosin, the emulsions separate on cooling, and will cause much trouble in mixing on the day after they are made. If the emulsion made from any hard soap found on the market is used on the same day that it is made, no trouble will be experienced. The "cold-stirred" formula is difficult to make with hard soaps. The writer has found it impossible to make emulsions by using any of the soap powders, even if flour is used as a stabilizer.

Before any spray material is applied to a tree it should be tested to determine if it is a perfect emulsion. To do this, add a small amount to some soft water; if no oil floats or no thick, greasy scum forms, it is satisfactory. If free oil appears the emulsion is imperfect and should not be used. Great care should be used to stir the contents of the barrel thoroughly before any test is made.

The present price of potash-fishoil soap makes the "cold-stirred" formula somewhat expensive, but when the market becomes normal its cost will be reasonable. It has an advantage in that it will keep indefinitely and will not separate under ordinary conditions of temperature or usage. Furthermore, no apparatus other than an ordinary pail and paddle is required for making it on a small scale.

Just at present the boiled-emulsion formula is the one which will appeal to the average citrus grower in Florida. It is, beyond all question, the cheapest effective insecticide for white flies and scale insects.

The oils used in the making of these formulas test from 21° to 32° Baumé and have a viscosity varying from 200 to 1,700. While it is not known just what physical properties an oil should possess to be of the greatest insecticidal value, experience seems to indicate that a satisfactory oil should have a viscosity perhaps greater than 500 and have a volatility test of less than 5 per cent. The greater the viscosity and the lower the volatility test the better the oil seems to be for killing scale insects. Petroleum fuel and distillate or gas oil may also be used and when applied should be used at twice the strength indicated for the lubricating oils. All the oils may be purchased from the various oil companies operating in the citrus belt. The soaps may be purchased from the various fertilizer companies.

PROPRIETARY MISCIBLE OILS AND EMULSIONS.

There are several proprietary miscible oils and emulsions on the market which give highly satisfactory results. These should be diluted so that the spray material will contain somewhere between ¾ per cent and 1 per cent of oil. The writer would advise the use of oil emulsions when diluted to about 1 per cent. Experience indicates that such substances as rosin oil and sulphuric acid should not be used in proprietary insecticides.

QUESTIONABLE INSECTICIDES.

Each year the citrus grower is besieged by representatives of new and untried alleged insecticides. Some of these may be found to possess merit, but more often they are spurious, or, at best, are not so good as the ones already on the market, or those that can be made by the grower himself. In some cases, even if they did possess value, the cost would be prohibitive. Recently an insecticide which when analyzed was found to contain 80 per cent kerosene with a touch of carbolic acid sold for $3 a quart. This would make the market value of kerosene not far from $14 a gallon, allowing $1 a gallon for other miscellaneous materials. The citrus grower should use a new insecticide only after it has been proved to be of value by a reputable firm or after the formula has been tested out by the station or department workers. In case the grower desires to experiment for himself with a new and untried insecticide, it should be applied to only a limited number of trees while the main spraying is done with well-tested materials.

SOFTENING HARD WATER.

Whenever practicable the growers should use lake water for spraying with the oil emulsions. When a proper emulsion is so used, no trouble will be experienced. If only deep-well water or sulphur water is to be had for spraying purposes, some means must be taken to eliminate those chemicals which combine with the caustic soda in the oil emulsions to set the oil free. If such water is used without treatment, free oil sometimes appears on the surface, but usually a thick, greasy mass forms. Usually when sprayed on a tree the twigs are killed to a considerable extent. Some of these well waters are so hard that it requires an enormous amount of soap to soften them. Our experience indicates that caustic soda when used alone will not give satisfactory results. It has been found that if 1 pound of caustic soda per 100 gallons is used in addition to from 3 to 6 pounds of soap the oil emulsion will mix satisfactorily. Caustic soda should be dissolved in 2 or 3 gallons of water and then added to the full tank and the entire mixture stirred and left to stand about a minute. Before adding, the soap should have been dissolved at the rate of about 1 or 2 pounds per gallon of water. After the soda and soap solution have stood for 2 or 3 minutes the insecticide may be poured in.

It is advisable for the grower to proceed on a small scale at first, using a barrel of water or less. After the first addition of caustic soda and soap some insecticide should be added. If the thick, greasy scum forms within the period of 5 minutes, another test should be made, using a larger quantity of both caustic soda and soap.

Weak Bordeaux mixture may also be used to render deep-well waters so that any oil emulsion will mix with them. The authors have never known ½–½–50 Bordeaux or 8 ounces of bluestone and 8 ounces of lime to 50 gallons of water to fail. In fact, in every instance except one, one-half this quantity gave satisfactory results. Dissolve the bluestone in water and add the lime, which has previously been dissolved in a gallon or so of water. After stirring, the oil emulsion can be added. The grower should note in using this as a water softener that the material will possess a flocculent precipitate and should be applied with a slow revolving agitator. Such spray material will also have more or less fungicidal properties.

SPRAYS FOR RED SPIDERS AND RUST MITES.

It has been known for many years that sulphur sprays are successful against both rust mites and red spiders. Lime-sulphur solution has no doubt been the best form of sulphur for the control of these pests. The advantage of this solution over other forms is its

permanency, since after it once dries on the leaves it remains for a considerable length of time, whereas other forms are easily washed off by rain or dissipated by dew. Directions for making lime-sulphur solution are given in other publications of the department.[18] For these pests it is best to use lime-sulphur solution not weaker than 1 gallon to 75 of water. The maximum strength to be used will depend entirely upon the season of the year and the objects of the grower in spraying.

During the last few years several substitutes for lime-sulphur solution have been placed on the market. Nearly all of these are dry or powdered. It is reasonably certain that they will produce equally as satisfactory results as lime-sulphur solution if used so that the spray material contains the same amount of sulphur in solution.

SODA-SULPHUR SOLUTION.

The main value of the soda-sulphur solution consists in the properties which enable it to be used in combination with the oil emulsions. Owing to the superiority of lime-sulphur solution the use of soda-sulphur solution alone is not advised. It has a distinct place, however, in forming a good combination spray for white flies, scale insects, and mites. It is made as follows:

Formula.

Flowers of sulphur	pounds	30
Caustic soda (98 per cent)	do	20
Water	gallons	20

To remove the lumps from the sulphur, place a wire screen over the barrel and rub the sulphur through with the hands, then slowly add about 3 gallons of water and stir so as to form a thin paste. The caustic soda should then be added and the entire mixture stirred vigorously. Some growers add the caustic soda gradually to prevent too vigorous boiling, and others add it all at once with water enough to prevent too vigorous boiling. It is also practicable to dissolve the caustic soda in about 4 gallons of water before it is added to the sulphur. The boiling will be quite violent and it may be necessary to add a gallon or more of water during the process, but whether or not this is necessary can be determined by the operator.

The main difficulty in making this formula is that too great heat is generated, which liquefies the sulphur before it can be acted on by the caustic. If sediment forms this has been the cause. To prevent this excessive heat add more water in the beginning and during the process. After boiling has ceased add about 16 gallons of water.

[18] Farmers' Bulletin 908, "Information for Fruit Growers about Insecticides, Spraying Machinery, and Important Insect Pests," by A. L. Quaintance and E. H. Siegler.

For spraying against red spiders and rust mites use 1 gallon of this stock solution to 40 gallons of water. *When used with the oil sprays* the strength should be a little less than if used alone. When so used dilute 1 gallon to 50 gallons of water. If it is to be used in combination with oil emulsion, it should be added to the tank or barrel of water before the oil emulsion.

SPRAY COMBINATIONS.

Since the oil emulsions kill white flies and scale insects and the sulphur sprays kill rust mites, the logical thing to do would be to apply the mixtures together, provided that the sulphur sprays and emulsions were compatible, and, furthermore, that the pests were present at the time. Such a combined use of the two main insecticides would save the expense of the labor necessary for applying them separately.

Soda-sulphur oil-emulsion spray.—The combination of oil emulsions and soda sulphurs makes a compatible spray and the mixture is always perfect. It is just as safe to apply as either spray separately. In May also a considerable infestation of rust mites is usually present, as well as white flies and scales. The use of this combination at this time should not keep citrus growers from making the main rust-mite spraying a month or so later. The use of the sulphur in the emulsion is simply to insure the fruit against any undue infestation of rust mites until such time as the grower can conveniently make the lime-sulphur spraying. Many growers have used this combination for many years and other growers have used it for a while and then stopped using it.

Oil-emulsion lime-sulphur sprays.—While any oil emulsion can be used with the soda-sulphur solution, this is not the case with lime-sulphur solution. In order to use the combination of oil emulsion and lime-sulphur it will be necessary to use a stabilized emulsion to prevent undue separation. Any emulsion which is made for deep-well water will mix and work satisfactorily with lime-sulphur solution. When this combination is used it should be noted that a large part of the insecticide is in the form of a flaky precipitate and it will be necessary to use an agitator to apply it. Although the author has used this emulsion to a rather large extent, no injury has ever resulted. The grower, however, should use this combination with much conservatism. He should be very careful that the mixture is right before applying it. Several growers at present are using this combination exclusively and with success. To those growers who have considerable skill and knowledge of spraying and insecticides, this combination is recommended at least for a thorough trial.

Bordeaux oil-emulsion combination.—This spray is used to control scab and melanose and other fungous diseases. The oil emulsion is added in order to prevent the undue infestation of scale insects which usually follows the plain Bordeaux. This combination is perfectly safe and will do no injury to either the fruit or the trees.

In all these combinations the oil emulsion, the sulphur, and the copper are just as effective in combination as they are when applied singly.

Sulphur sprays and tobacco solutions.—This combination is used for thrips in the bloom and will cause no damage.

FACTORS IN OBTAINING SUCCESSFUL RESULTS.

In order to obtain satisfactory results from spraying, the grower should carefully plan the operations a considerable time in advance.

PRELIMINARY WORK.

A spraying outfit should be ordered at least two months before it is needed. If a spraying outfit is already at hand, great care should be taken to overhaul it at least a month before spraying begins. This will afford plenty of time to send for parts, if any need to be replaced. The tank should be cleaned out, and soaked so that it will not leak. The pump should be carefully repaired, and if any parts are worn out or broken they should be replaced. It is essential that the valves be in perfect condition and these should be polished with emery dust or emery cloth. The valve seats if worn should be changed or new ones substituted. It may be that these can be reamed out by a machinist. In case any gears are badly worn, new ones should be obtained. The engine should be carefully gone over to see that it is ready for operation. If the cut-offs leak they should be replaced or ground, and the nozzles and rods examined. In regard to the hose, it is always advisable to have an extra lead in case those in use leak badly.

The insecticide or insecticide material for the entire grove should be on hand at least a week or 10 days before operations are to be begun. It is better to overestimate a little than to underestimate the quantity, as in the latter case the spraying operations would have to cease until another supply could be obtained.

The source of water supply is also very important. For the oil emulsions it is much better to use lake water, but if this is impossible the water from the deep wells can be used and treated as heretofore suggested. If sulphur sprays are to be used alone they will mix satisfactorily with both lake and deep well water. Wherever practicable the water should be hauled to the machine by a supply team (fig. 14). Where two leads of hose only are being used, this hauling can be done

with one horse and a boy with two barrels, unless, of course, the water supply is at a great distance. When four leads of hose are being used, it will be necessary to use a double team and four barrels or a supply tank. If it is possible to haul the water for spraying to the machine, the number of trees sprayed can be practically doubled. In operations conducted by the writer as many as 18 loads of 200 gallons each have been sprayed in 10 hours. When the water is hauled to the machine the tank filler or suction pipe may be inserted into one barrel while the spray men, with buckets, dip the other three barrels into the tank. This saves much time in filling.

Before any insecticide is used its strength should be known in order to permit the dilution of the spray to the proper strength. The oil emulsions should be diluted according to the percentage of oil they contain. The sulphur solutions should be diluted according to the quantity of sulphur in each gallon of liquid, which is usually told by the degree of density as determined by the hydrometer.

It is also of considerable convenience to be able to open a barrel in the proper manner without breaking in the head. To do this take an ax or other implement and pound first on one side of the bung and then on the other. After a few such strokes the bung will be loosened so that it can be very easily removed or "jumped" out. After this is done a paddle should be inserted through the bunghole to stir the insecticide. The insecticide should always be stirred before any is taken out for spraying. It is convenient also to nail a small piece of tin on one side of the bunghole which will act as a spout and cause the insecticide to run into the measuring bucket instead of down the side of the barrel. A hole also can be bored in the head about 1 inch from the edge on that side of the barrel which is opposite the bunghole. A faucet or molasses gate should then be inserted in the hole, and the barrel placed on its side with the faucet next the ground. The bung should then be removed to permit stirring and entrance of air. A stick can be used for this purpose. The best way to mix an insecticide is to draw off several bucketfuls through the faucet and pour back through a funnel in the bunghole.

SPRAYING PROCEDURE.

HOW TO APPLY THE SPRAY.

In spraying for the control of white flies and scale insects the method of application is the same whether a barrel pump or a power outfit be used. The object should be the complete wetting of both the upper and lower surfaces of the leaves as well as all the limbs and the trunk.

In applying the spray the operator should begin on the far side of the tree and work around to the point nearest the machine. The

second half of the tree should be handled in like manner. If two operators are at work on the same tree they should both begin at the point farthest from the machine and proceed until they meet.

The spray should be applied to the tree in a systematic way. The operator should begin at the base and work to the top, inserting the rod among the branches so as to spray the center of the tree. The entire tree may be thus sprayed in sections, the operators proceeding alternately from the bottom to the top and from the top to the bottom. To prevent kinks in the hose, the operator in moving from tree to tree should never make a complete turn. In case kinks appear they should be immediately taken out by turning the spray rod and not by pulling the hose. In pulling kinks out of hose the hose fabric is destroyed. Such an avoidable waste of property should not be permitted.

PRESSURE.

The pressure that should be maintained depends to a considerable extent upon the agility of the man using the rod. If a man moves rapidly, a greater pressure can be maintained without accompanying loss of material than when a man moves slowly. A slow man will not be able to handle a much greater pressure than 150 pounds, whereas an active one will handle 250 pounds. It is very doubtful if a slow-moving man should be employed to use a spray rod. The pressure also depends upon the size of the hole in the disks. The smaller the hole, the greater must be the pressure to furnish sufficient spray material to wet the foliage without losing time. If a barrel pump is used, from 80 to 100 pounds will be all that can be held with one man pumping. From 100 to 125 pounds will be all that can be maintained when the large lever pump is used with one man pumping. For average conditions the power outfit should maintain from 175 to 250 pounds. When the pressure is less than 175 pounds operations should cease.

QUANTITY OF LIQUID REQUIRED TO WET TREES.

Successful results can not be obtained unless sufficient material is used to wet the foliage completely. To a certain degree the quantity of liquid used is a good criterion of the efficiency of the spraying done. We have known intelligent grove owners to use a gallon of material for a tree 10 feet high. No satisfactory results can be expected from such spraying. The quantity to be used will depend upon the density of the foliage as well as upon the size of the trees. Small trees having dense foliage require much more material than do larger trees with more sparse foliage and straggling branches. For trees 1 or 2 years old one-half to three-fourths of a gallon is sufficient. Trees 3 to 4 years old should require from 1 to 1½ gallons,

and trees just beginning to bear should seldom receive less than 2 gallons per tree. Trees of large spread and 10 feet in height sometimes require 10 gallons, while the very largest trees require as much as 15 gallons. The average tree of 10 to 12 feet requires about 8 gallons.

RAINS AND DEWS.

Spraying should never be done during a rain or when the foliage is dripping wet. Spraying under such conditions dilutes the spray to such an extent that it is entirely ineffective in killing the pests. Operations should cease at least 10 minutes before a shower, in order to give the spray a chance to dry. After a shower operations should be resumed in 20 to 30 minutes, or after a large part of the drip has ceased. If heavy showers fall late in the afternoon, it is improbable that spraying resumed the same day will be effective. It is seldom that the dew is so heavy as to prevent spraying at 7 o'clock in the morning.

THOROUGHNESS.

In spraying for any pest on citrus trees the complete wetting of every leaf on both surfaces as well as the branches and trunk should be accomplished. It is only when leaves are hit by the spray that the pests on them are killed. *Lack of thoroughness in this respect is responsible for more failures to obtain satisfactory results than are all other factors combined.*

In order that satisfactory results may be secured, only the most intelligent, honest, and careful laborers should be employed to handle the spray rods. In fact, it might be well for the foreman or owner to handle one rod. If this is not practicable, the owner or a responsible foreman should be with the machine all the time. It is also advisable to examine the leaves frequently to see if they have been hit on the lower surfaces. The sprayer himself should have an opportunity to examine his own work. Even when the best and most thorough work has been done, many leaves will remain untouched by the spray.

WHEN TO SPRAY.

So far as the effect of the various insecticides on the trees and fruit is concerned it is reasonably safe to spray at any season of the year. The oil emulsions, however, should not be used at more than half strength during the blossoming period (compare figs. 18 and 19) or until the fruit is about an inch in diameter. Although the writer has known several people to use them at this season at full strength without any injurious results, the application of oil sprays to the blossoms is too hazardous to be generally practiced. When low tem-

peratures follow the application of oil sprays, an excessive shedding of foliage usually occurs. Spraying operations that are being carried on during the winter should be discontinued as soon as a cold wave is predicted. The sulphur sprays, either alone or in combination with the tobacco solutions, usually will cause no damage to the blossoms if used at any recommended strength. Neither will the tobacco solutions cause any damage to the blossoms even if used at several times the recommended strength. If it is the intention to spray during the winter, it will be found much more convenient to spray after the fruit has been removed. The insecticide usually will do no harm to the fruit, but the spraying operations may cause more or less mechanical injury when the branches are heavily laden with fruit. It is also difficult to do as thorough work when the branches are weighted with fruit.

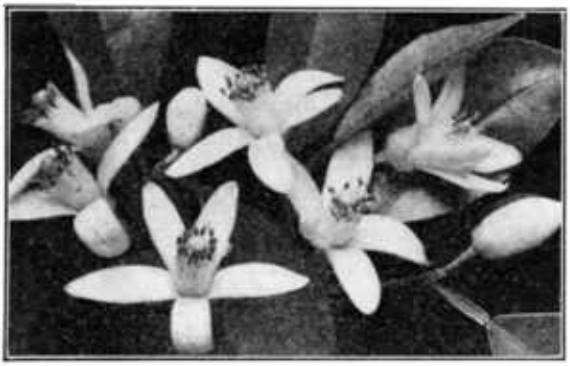


FIG. 18.—Normal orange blooms and buds. Compare with the bloom in figure 19.

The life history and habits of nearly all pests on citrus trees are, fortunately, such that good and satisfactory results can be obtained at any time the spray is applied, but to obtain the maximum benefit with the minimum expense the spraying must be opportune. Much of the spraying done at present brings no returns to the grower, because it is done after the damage has taken place. The writer has seen many groves being sprayed when the purple scale had al-

FIG. 19.—Spraying with heavy oil emulsions at full strength may injure the bloom of orange and grapefruit, as here illustrated, and cause much of it to drop.

ready done $2 worth of damage per tree. Men also have been seen spraying where the pests were so few that practically no beneficial results would ever follow the treatment. *The spraying for rust mites is often done when not more than two or three mites can be found on a fruit, or after they have become so numerous that the russeting has already appeared and could not be prevented by any amount of spraying.*

As a general rule, the time to spray for the control of pests on citrus trees is when they are present in such numbers that if left to reproduce without artificial hindrance they would soon become injurious. The pests should not be allowed to increase to a point where they attract noticeable attention, as in figure 20. In case the various pests of citrus trees are permitted to become so abundant as to cause damage, the profits which might be derived from artificial treatment, such as spraying, are to a certain extent lost.

FIG. 20.—An orange leaf heavily infested with the citrus white fly. There are over 800 pupæ and pupa cases on this leaf. The white fly should never be permitted to become as abundant as here shown. (Morrill and Back.)

Specifically, then, what should guide the citrus grower in deciding just when spraying should be done or if it should be done at all? The difficulty in answering this question arises from the fact that the extent of the future infestation of any pest is so influenced by weather conditions and natural enemies that it is impossible to make predictions approximating any degree of accuracy. A few suggestions are given here to help the intelligent grower to handle this most difficult of all problems.

Six-spotted mite.—In the control of the six-spotted mite spraying should be done in March, April, or May, if one or two trees are badly infested or if many trees are slightly infested. This pest spreads most rapidly in the dry spring months, and complete defoliation often follows while the grower is contemplating spraying. After the rainy season sets in trouble is rarely experienced with this species.

Rust mite.—The rust mite causes blemishes on the fruit known as russeting, tearstain (fig. 21), and sharkskin or a silver scurf. Being of small size, it often reaches the maximum infestation before the growers know of its presence. The first intimation of its presence is evidenced by the "russet" fruit, and then it is too late to remedy the damage. The grower should provide himself with a hand lens to enable him to see this serious pest. If there are about 50 mites on each of the old leaves in the spring, spraying should be done within the next few days. Another rule to follow is to spray when the mites are abundant on the foliage and just beginning to appear on the young fruit. If the fruit is about 1½ inches in diameter and a few fruits per tree look a little brownish, the time is short before spraying should be started to get bright fruit. If in either April, May, or June, from 100 to 200 mites are on each fruit, spraying should be done within the next two weeks. At other times a greater number could be present without russeting the fruit.

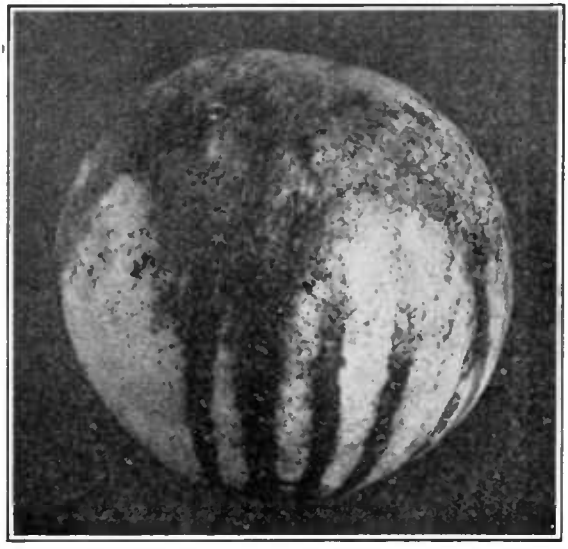


FIG. 21.—Rust-mite tearstain on grapefruit.

Scale insects.—For scales spraying should be done before any of the limbs or branches are killed or any of the leaves have turned yellow. Treatment on all the trees should be given before the center is killed out.

White flies.—The object in spraying for white flies is to keep the sooty mold (figs. 22 and 23) from both the leaves and fruit. When each leaf has an average of from 6 to 10 pupæ in the spring, spraying should by all means be given in May. Unless the grower has

acquired considerable judgment as to when spraying should be done, it might be well to follow some such scheme as here given.

SPRAYING SCHEDULE RECOMMENDED.

The following spraying scheme has been used extensively for several years and generally has given satisfactory results. No hard and fast scheme can be given, however, and the number of sprayings depends to a large extent on the thoroughness of the work and the abundance of the pests.

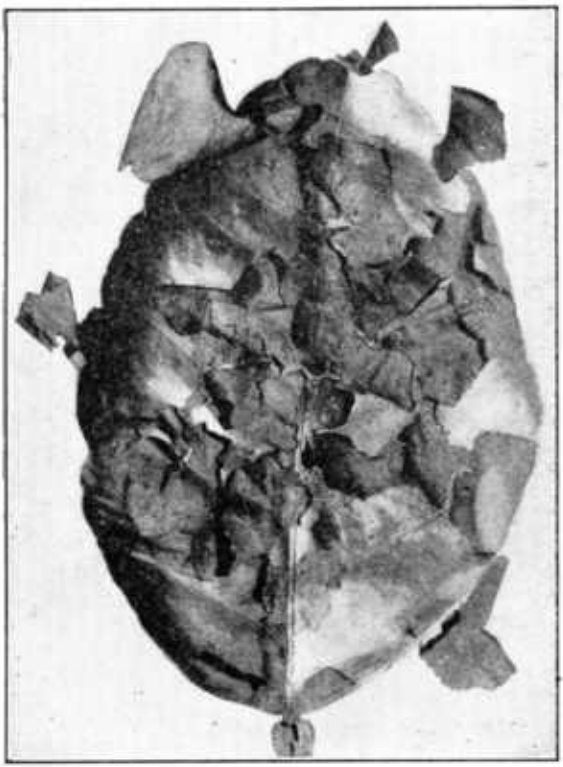


FIG. 22.—Oil-emulsion sprays cause the sooty mold following white-fly attack to break and fall from the foliage and branches. A strong breeze or heavy rain two or three days after trees have been sprayed usually will take off all or nearly all the sooty mold from the tree. (Morrill and Back.)

1.—Paraffin-oil emulsions: Government formula, 1 per cent of oil—May: The main object of spraying at this time is to kill white flies, scale insects, and to a large extent rust mites, although this treatment must not be relied upon to control the last pest. The spraying should be given after the adults of the first brood of white flies have disappeared and before the appearance of those of the second brood (see fig. 24). The fruit should be an inch or more in diameter. This treatment should be given before the beginning of the rainy season, so that the entomogenous fungi will attack those insects not killed by the spray. Soda-sulphur 1 gallon to 50 or 1½ pounds of the dry form may be added to the oil-emulsion spray. This combination will be much more effective against rust mites than the oil emulsion alone and will insure the fruit from rust-mite injury until the regular spraying for rust mites is given with lime-sulphur.

2. Lime-sulphur solution, 32° Baumé, 1–50 to 1–75 gallons of water—April, May, June, to July: The main object of this treatment is to kill rust mites, thereby eliminating such blemishes as russeting, tearstain, and sharkskin, or silver scurf, and the best time for its application varies with the appearance of the maximum number of rust mites. It should be applied before the mites get very abundant and before russeting appears. In the more southern sec-

FIG. 23.—Heavy coatings of sooty mold on oranges and grapefruit prevent the fruit from coloring normally. The rind remains green beneath the layers of sooty mold. Spraying with oil emulsion breaks up the sooty mold as illustrated, thus giving the sun a chance to color the fruit.

tions it may be necessary to apply this spray in April. This is especially true if sharkskin on the grapefruit has been prevalent. About the middle of June, however, is usually the most opportune time to spray oranges. This treatment will also kill some scales and white flies, but is of little value for that purpose.

3.—Paraffin-oil emulsions: Government formula, 1 per cent of oil—August 25 to October 31: This is the second spraying for the white

fly and scale insects. The object of spraying at this time is to kill all the white-fly larvæ which are the progeny of the third and last brood. It is this brood which causes nearly all the damage from the white flies, and the earlier they are killed the better it is for the tree. This will also remove the sooty mold from the leaves (fig. 22) and from the fruit (fig. 23) so that the sun can color the fruit. Soda-sulphur 1–50, or 2 pounds of the dry form, may be added to this spray to increase its effectiveness in killing rust mites.

4.—Lime-sulphur solution, 32° Baumé, 1–50 to 1–75 gallons of water—November or December: The object of this spraying is to kill rust mites, and it may or may not be necessary, depending on the abundance of the mites.

It may be necessary to spray for rust mites and red spiders before No. 1 is given. This is especially true for grapefruit in the more southern counties of Florida. If such a spraying is given, it should be in the midst of the blossoming period, using lime-sulphur

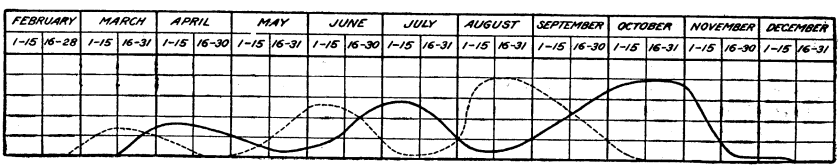


FIG. 24.—Diagram showing relative abundance of adults of the cloudy-winged white fly (solid line) and of the citrus white fly (dotted line) throughout the year 1909, at Orlando, Fla. (Morrill and Back.)

1–40, which will kill rust mites, red spiders, and young scales. It is advisable to add nicotine sulphate 1–1,200 if thrips are abundant. It may also be necessary to spray three times with the oil sprays, in which case this treatment can be given in midsummer or in winter. If the red scale is very abundant, two sprayings with the oil emulsions, used at double strength, should be given at intervals of about six weeks.

On nursery trees one application of emulsion used at three times the regular strength will control this pest.

THE EFFECT OF INSECTICIDES ON PESTS.

The fish-oil soap and the oil sprays kill the insects by asphyxiating them. The oil sprays kill the adults, eggs, larvæ, and pupæ of the white flies. It is not difficult to determine whether the larvæ and pupæ of the white flies have been killed, for they turn brownish 3 to 10 days after the spray has been applied (fig. 25) and may be brushed easily from the leaf. A month or more afterwards those which have been killed are quite brown and somewhat dried up. In many cases the eggs of the white flies never hatch, while in other

instances the young larvæ are killed by the oil immediately after they emerge from the shells. Thousands of such larvæ have been observed adjoining the eggshells from which they have emerged.

The oil sprays kill all stages of the purple scale, and in many cases all the eggs of some females are prevented from hatching In other cases the oil enters the opening in the rear of the scale covering and prevents a row or two of eggs nearest the opening from hatching. In the natural course of events the eggs nearest the opening hatch first, since they were deposited first. This gives those young scales that hatch from eggs farther from the opening plenty of opportunity to emerge. When the first row or two of eggs is prevented from hatching, the exit is stopped. This prevents those young scales from emerging that hatch from eggs not affected by the oil film. Thus almost complete mortality results.

The oil spray used at a strength of 2 per cent kills the young stages of the red scale and in most cases the adult females, but the scale covering is fastened so closely to the leaf or fruit that the eggs are seldom harmed. A second spraying must be given after these hatch and develop into the young stages.

The sulphur sprays are extremely effective in killing rust mites. The action is rapid, the bodies of the mites being largely destroyed by the caustic nature of the spray. When on the fruit a few are washed to where the drop of spray collects, and there their dried bodies may be seen after the spray has evaporated. The eggs also are killed if the spray is used at the recommended dilutions.

The sulphur sprays are very effective also in killing the purple and six-spotted mites. The killing action is rapid, but the bodies are not completely destroyed by the caustic nature of the spray as is the case with rust mites. The spray does not prevent the eggs from hatching, but the presence of the spray usually kills the young mite as soon as it emerges from its eggshell. Thousands of newly hatched dead mites have been observed near the eggshell from which they had just emerged. While the oil sprays usually prevent an egg from hatching, the sulphur sprays more often kill the young "crawler" as soon as it hatches.

DUSTING FOR MITES.

All mites are extremely sensitive to sulphur in any form. When the six-spotted mites come in contact with fine sulphur they become exceedingly active at first, run about in a wild and aimless manner, gradually become quiet, and finally die. The purple mite is also quickly killed by sulphur. When sulphur comes near rust mites death is instantaneous.

For dusting purposes both flour and flowers of sulphur may be used. These are highly satisfactory used either alone or mixed

with hydrated lime in the proportion of 90 per cent sulphur and 10 of lime. These materials are applied by means of a dusting machine and dusting may be done in the daytime when the foliage is dry. One application will kill all mites present on the trees; and if not washed off by rains will remain long enough on the leaves to kill the young mites as they hatch from the eggs. If rains come within three or four days after dusting, it will be necessary to dust again at once.

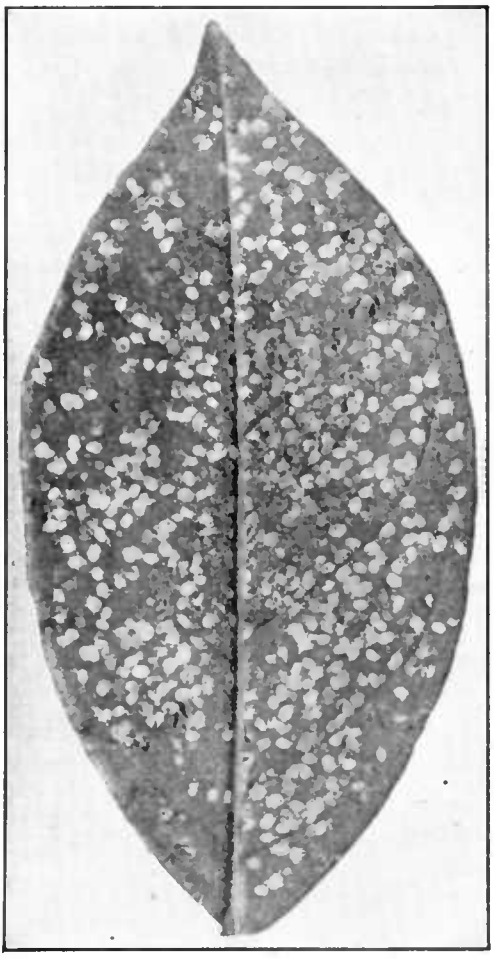


FIG. 25.—Pupæ of the citrus white fly. When living the pupæ are seen with difficulty, but after they have been killed, as in the illustration, they turn brown and one can then easily see how thin and scalelike they really are. (Morrill and Back.)

SPRAY INJURIES.

Under average conditions of temperature and moisture the oil sprays will not cause any noticeable injury to either the foliage or the fruit. New growth often starts in a few days after the killing of the insects. A large percentage of old leaves, now functionless, fall about the third day following the application of an oil spray. Good leaves very seldom fall. In the experiments 2 per cent of oil, or twice as much as required, has been used extensively without causing normal leaves to fall prematurely. In small tests 3 per cent of oil in the diluted spray material caused no damage. No injury follows spraying either before or during a rain, and neither does humidity appear to be a factor in causing injury. When the oil emulsions are used, whether made of kerosene or heavy lubricating oil of 24° Baumé, shadows sometimes appear on the fruit. These shadows usually follow spraying during hot, bright days when the

temperature is above 91° or 92° F. As the temperature is very high, the heat evaporates the water in the spray material before it has had time to run off. This concentrates the oil in one spot and causes a slight damage to the stomata, resulting in a darker shade of green than the surrounding area. These dark-green shadows disappear not later than a week or two after the fruit has colored in the fall, and it is impossible to locate the previous discolorations if these have not been marked. Sometimes the damage is limited to the spot where the drop of spray has collected. The only way to avoid such damage would be to cease spraying when the temperature rose above 92° F. This injury occurs only occasionally.

The application of the oil sprays two or three times a year at the recommended strength has never been known to cause devitalization of the trees. If an excessive amount of spray is used the normal growth of the leaves is interrupted. They do not reach the proper size, become thin, and the tree has the appearance of being stunted. The fruit also is small, does not color up properly or at the proper time, and is sour when other fruit is sweet. Such a condition only follows the application of from three to six times as much oil as the worst infestation of white flies and scale insects requires. Two applications within one month of a 2 per cent solution in 1916 did no noticeable damage to either the tree or the fruit.

Soda-sulphur solution very seldom, if ever, causes any damage to the trees or fruit. No accumulated ill effects have been known to follow the use of this spray. This noninjuriousness is no doubt due to its lack of stability, since it is easily washed off by rains and dissipated by dews.

Lime-sulphur solution, dry lime-sulphur, and barium tetrasulphid do not cause damage at the recommended dilutions under average conditions. When the temperature is 92° F. and the sun is bright, injury to the fruit sometimes follows. In all the experimental work such injury followed on only one occasion. The injury is always located on the side of the fruit turned to the sun at the particular time of day when the spraying was done. The exact cause of this type of injury is not yet fully understood, but it is very certain that it should not be considered as being due to the insecticide alone, but to the combined action of the sun and the insecticide. When the injury is caused by the insecticide alone, the blemish will be found at the place where the drop of spray collects on the lower surface of each fruit.

Instead of injuring citrus trees, lime-sulphur solution has a stimulating effect. The leaves become a darker green and the fruit reaches a larger size. Fruit has been known to ripen at least three weeks to a month earlier than other fruit of the same kind in an adjoining row. The exact cause of this is not known, but the spray evidently

has some direct action on the leaves. Careful experiments have shown that there is no known spray so beneficial to citrus trees as is lime-sulphur solution.

COST OF SPRAYING.

The cost of spraying (Table 1) necessarily varies and depends upon the size of the trees, the density of the foliage, the equipment used, and the nearness of the grove to the water supply. Accurate estimates of the probable cost can be computed only after all these factors have been taken into consideration. Nursery trees can be sprayed for one-sixth of a cent each, while the largest trees will cost as much as 10 cents. Trees with dense foliage require much more insecticide and a longer time to spray than those with sparse foliage, even though the latter may be much larger trees. If the spraying is done with a barrel pump the cost will be somewhat greater than if done with a power outfit. The item of labor will be not far from 75 per cent of the total cost. If the water supply is in the grove or very close, the cost will be considerably less than if it is some distance away. A water supply a greater distance away than half a mile is not practicable, because it would require two extra teams to supply one machine. This would increase the cost about 1½ cents per tree.

In computing the cost of spraying the depreciation of machinery should always be included. Many inquiries were sent to citrus growers for information on this point. Some estimated the depreciation to be as great as 25 per cent. One grower thought it would be as low as 10 per cent, but it was the opinion of the majority that from 15 to 20 per cent would be more consistent. This appeals to the writer as the proper estimate to be placed upon this phase of the cost of spraying. The percentage of depreciation will depend almost entirely upon the care that is given the machine. The length of time a machine will be serviceable depends much more upon the care it receives than upon the amount of work it does.

The writer has obtained from many growers the actual cost figures for spraying done on a commercial basis under the average grove conditions prevailing in Florida. These will assist any grower contemplating a spraying program in arriving at an accurate estimate of the probable cost. These statements include the depreciation of machinery as well as cost of labor, team hire, insecticides, and incidentals, but naturally can not be construed to apply to such unusual conditions as those bearing on a local shortage in chemicals due to unprecedented freight congestion, or to a deficiency in the supply of the chemicals in the United States generally.

TABLE 1.—*Cost of spraying.*

Grove No.	Number of boxes of fruit per tree.	Acres.	Number of trees.	Applications per year.	Cost.			Distribution of cost.			Incidentals.	Remarks.
					Per box.	Per tree.	Per acre.	Insecticides.	Labor.	Team.		
								P. ct.	*P. ct*	*P. ct.*	*P. ct.*	
1	10	7½	450	7	.....	0.50	$30.00	.....	.....	.....	.....	
2	12	.....	4,316	1	.....	.097	.....	34	29.4	32	4.5	
3	12	.....	1,239	3	0.0267	.109	.....	26	28	35	11	
4	15	.....	300	5	.050	.66	.....	.....	.....	.....	.....	
5	8	10	650	2	.056	.....	11.00	40	.....	.....	.....	
6	10	260	.....	5	.0438	.....	.....	.....	.....	.....	.....	
7	10	.....	6,367	5	.....	.21½	.....	46	.....	.....	.....	
8	10	10	650	3	.....	.21½	14.00	48	.....	.....	.....	
9	10	260	.....	5	.06	.....	.....	50	.....	.....	.....	
10	7	300	.....	.....	.06	.....	.....	.....	.....	.....	.....	
11	8	.....	1,000	1	.....	.08	.....	.....	.....	.....	.....	
12	8	40	.....	4	.055	.....	.....	.....	.....	.....	.....	
13	10	550	.....	1	.....	.....	3.00	.....	.....	.....	.....	
14	18	35	.....	6	.05	.....	.....	.....	.....	.....	.....	
15	10	.....	1,909	1	.....	.08	.....	44	35	21	.....	
16	10	.....	1,800	1	.....	.083	.....	.....	.....	.....	.....	
17	8	60	.....	4	.05	.16	.....	.....	.....	.....	.....	
18	8	120	6,360	4	.06	.20	.....	64	36	.....	.....	
19	8	20	1,600	1	.....	.06	.....	45	55	.....	.....	
20	8	.....	2,125	1	.....	.08	.....	57	36	.....	7	
21	8	.....	1,343	1	.....	.78	.....	24	65	.....	11	
22	6	.....	.....	3	.....	.15	.....	.....	.....	.....	.....	
23	.....	.....	400	1	.022	.76	.....	19	68	13	.....	Hand pump.
24	5	.....	778	3	.....	.194	.....	36	64	.....	.....	1914 pump.
25	5	.....	778	3	.....	.20	.....	27	73	.....	.....	1915 pump.
26	7	.....	500	1	.29	.....	.....	25	35	30	.....	

The figures of Table 1 show that it will cost from $3 to $5.50 per acre per application to spray the average bearing grove. The cost per box is also seen to be from 1 to 1½ cents for each application and the cost per tree from 5 to 10 cents. To carry out any annual spraying schedule it will cost about 6 cents per box, 20 cents per tree, and about $15 per acre. The cost of spraying young trees is very small. One nurseryman sprayed 40,000 trees with the oil spray for less than one-sixth of a cent each. Young grove trees from 1 to 3 years old can be sprayed for about 1 cent each.

PROFITS FROM SPRAYING.

After many years of work it is still impossible to express the percentage of profits to be expected on money expended in spraying for the control of citrus pests. This same condition, however, applies to every grove operation in Florida. The profits which may arise from following a spraying schedule are due to the raising of the grade of the fruit and increasing the yield by preventing the devitalization of the trees following insect attack. (Compare figs. 26 and 27.) A detailed statement of the profits a grower should expect from spraying has been published in Department Bulletin 645, "Some Reasons for Spraying Citrus Trees in Florida,"[19] and the reader is

[19] This may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 5 cents (postage stamps not accepted).

referred to that publication for the complete discussion of this phase of the spraying question.

In that bulletin it was shown that in the 1915–16 citrus crop there was a loss of over $500,000 due to the lowering of the grades of the

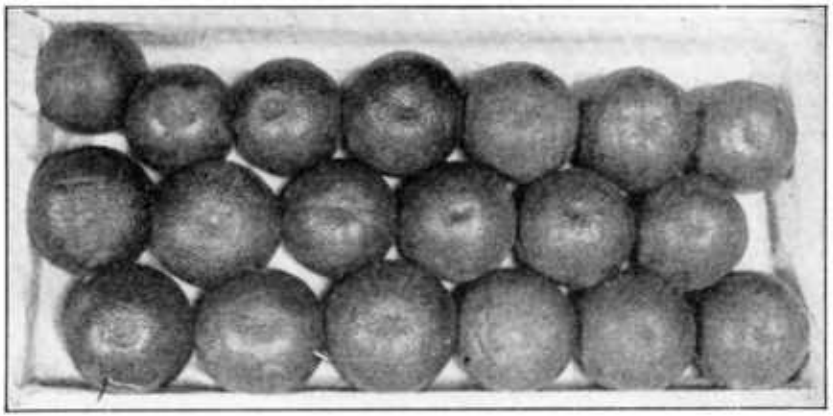


FIG. 26.—A miscellaneous lot of fruit picked from trees sprayed to kill rust mites. Only 19 fruits could be packed in the tray. Compare fruits shown in figure 27.

fruit, caused by pests, which could have been prevented very easily. The reduction in size caused an additional loss of $475,000, and the reduction in yield caused a loss of $760,000, making a total of

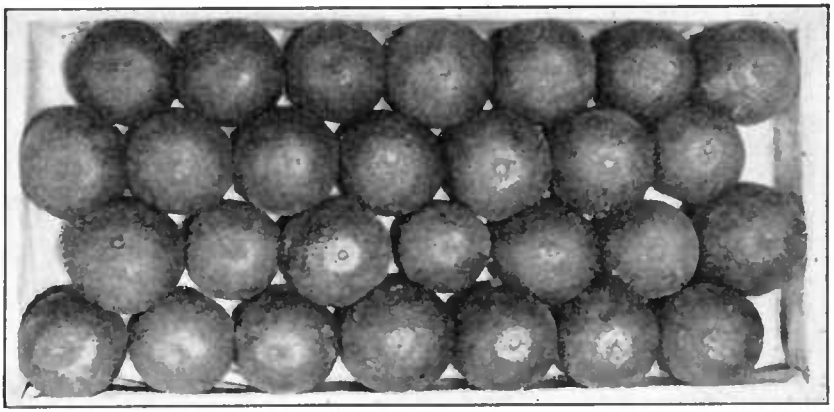


FIG. 27.—A miscellaneous lot of oranges from unsprayed trees adjoining sprayed ones. Note that these 28 fruits take up the same space as the 19 fruits from sprayed trees shown in figure 26. Spraying increases the size of the fruit.

$1,744,955, practically all of which could have been prevented easily at a nominal cost. To spray this crop at 6 cents per box would have cost $456,000, leaving a profit of $1,288,955, or 282.7 per cent profit on the investment.

In addition to these profits there are benefits that can not be expressed in a money unit. The better the fruit the greater its marketability. High-grade fruit can be sold when the owner desires to sell it; the lower grades can be sold when the buyers want it, or when the market calls for the lower grades. Many growers consider this a most important item. There is much satisfaction in growing fine fruit and owning healthy trees. This makes orange growing fascinating.

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